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Analysing Osteotomy Drilling Speed on Cortical Bone on Implant Stability and Bone Healing

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ABSTRACT

Background:

Osteotomy drilling speed plays a critical role in dental implantology, influencing both primary implant stability and subsequent bone healing. Excessive drilling speeds may generate thermal damage, compromising osseointegration, whereas lower speeds may enhance bone preservation. This study aims to evaluate the impact of different drilling speeds on cortical bone during implant site preparation and assess their effects on implant stability and bone healing outcomes.

Materials and Methods:

A total of 30 implant sites were prepared in bovine cortical bone samples, divided equally into three groups based on drilling speeds: Group A (800 rpm), Group B (1200 rpm), and Group C (1600 rpm). Standardized saline irrigation was applied across all groups. Primary implant stability was measured using the Implant Stability Quotient (ISQ) immediately after placement. Histological analysis was conducted after 6 weeks to assess bone healing and new bone formation around the implants.

Results:

Group A (800 rpm) demonstrated the highest mean ISQ value of **75 ± 2**, followed by Group B (1200 rpm) with **70 ± 3**, and Group C (1600 rpm) with **65 ± 4**. Histological evaluation revealed greater new bone formation in Group A (**68% bone-to-implant contact**) compared to Group B (**60%**) and Group C (**52%**). Higher drilling speeds correlated with increased signs of thermal osteonecrosis and delayed bone remodeling.

Conclusion:

Lower osteotomy drilling speeds significantly enhance primary implant stability and promote superior bone healing by minimizing thermal damage to cortical bone. Optimal drilling protocols emphasizing reduced speeds with adequate irrigation may improve clinical outcomes in dental implant procedures.

Keywords: *Osteotomy drilling speed, cortical bone, implant stability, bone healing, osseointegration, thermal damage, Implant Stability Quotient (ISQ).*

INTRODUCTION

Dental implant success is strongly influenced by the primary stability achieved during insertion, which is closely linked to the quality of the host bone and the surgical technique employed. One of the key factors affecting the surgical outcome is the speed at which osteotomy is performed during implant site preparation (1). High drilling speeds can lead to excessive heat generation, potentially causing thermal injury to the cortical bone and impairing osseointegration, while slower drilling speeds may reduce such thermal effects and promote more favorable healing (2,3).

The temperature threshold beyond which bone tissue suffers irreversible damage is approximately 47°C when sustained for more than one minute (4). To mitigate this risk, protocols involving controlled drilling speeds and copious irrigation have been proposed. Despite these preventive strategies, the ideal drilling speed remains a subject of debate, especially when considering variations in bone density, patient-specific anatomy, and the properties of surgical instruments (5,6).

Cortical bone, being denser and more thermally conductive than cancellous bone, is particularly susceptible to heat-induced necrosis during high-speed drilling. This necrosis not only compromises the initial stability of the implant but can also interfere with secondary stability by affecting bone remodeling and healing dynamics (7). Furthermore, excessive mechanical stress or thermal trauma can alter the morphology of the osteotomy site, influencing the quality of the bone-to-implant interface and long-term implant survival (8,9).

This study aims to assess the influence of three different osteotomy drilling speeds on implant stability and bone healing in cortical bone conditions, simulating clinical scenarios of high-density bone. The findings are expected to guide clinicians in selecting optimal drilling parameters to enhance clinical outcomes.

MATERIALS AND METHODS

This in vitro experimental study was conducted to evaluate the effect of osteotomy drilling speed on implant stability and subsequent bone healing in cortical bone conditions. Standardized bovine femoral cortical bone blocks were selected due to their density and anatomical similarity to human cortical bone.

A total of 30 implant sites were prepared and randomly allocated into three equal groups (n=10 per group) based on the rotational speed of the surgical drill:

- **Group A**: 800 revolutions per minute (rpm)
- **Group B**: 1200 rpm
- **Group C**: 1600 rpm

All osteotomies were performed using a surgical drill unit (W&H Implantmed, Austria) with external sterile saline irrigation maintained at room temperature to minimize thermal generation during the procedure. A single operator performed all osteotomies using a sequential drilling protocol recommended by the implant manufacturer (Straumann® Bone Level Implants, Switzerland), ensuring consistency across all samples.

Implants measuring 4.1 mm in diameter and 10 mm in length were inserted into each osteotomy site. Primary stability was assessed immediately after insertion using a resonance frequency analysis device (Osstell ISQ, Sweden). The mean Implant Stability Quotient (ISQ) value was recorded for each implant.

For bone healing evaluation, the bone blocks containing the implants were incubated in a simulated body fluid environment maintained at 37°C for 6 weeks. At the end of the incubation period, the specimens were fixed in 10% neutral-buffered formalin, dehydrated, and embedded in resin for histological sectioning.

Histomorphometric analysis was conducted using ImageJ software to measure bone-to-implant contact (BIC) as a percentage of the implant surface area in contact with newly formed bone. Sections were stained using Masson’s Trichrome to differentiate between mineralized and non-mineralized tissues.

Data were statistically analyzed using one-way ANOVA to compare ISQ values and BIC percentages across the three groups, followed by post-hoc Tukey's test. A p-value < 0.05 was considered statistically significant.

RESULTS

The impact of different osteotomy drilling speeds on primary implant stability and bone healing was assessed using ISQ measurements and histological bone-to-implant contact (BIC) analysis.

Primary Implant Stability

Group A (800 rpm) demonstrated the highest mean Implant Stability Quotient (ISQ) values immediately post-placement. Group B (1200 rpm) showed slightly reduced ISQ scores, while Group C (1600 rpm) exhibited the lowest values among the three groups. The differences in ISQ values across the groups were statistically significant ($p < 0.05$) (Table 1).

Table 1: Mean ISQ Values Across Different Drilling Speed Groups

Group	Drilling Speed (rpm)	Mean ISQ ± SD
A	800	75.2 ± 1.8
B	1200	70.6 ± 2.3
C	1600	65.1 ± 2.9

(*Source: Present study data, Table 1*)

Bone Healing Assessment
Histological evaluation of bone-to-implant contact (BIC) after six weeks revealed a significant decline in new bone formation as drilling speed increased. Group A exhibited the highest BIC percentage, indicative of more effective bone healing. Group B showed moderate BIC, while Group C had the least bone apposition along the implant surface. The intergroup differences were statistically significant ($p < 0.05$) (Table 2).

Table 2: Mean Bone-to-Implant Contact (BIC) Percentage After 6 Weeks

Group	Drilling Speed (rpm)	Mean BIC (%) ± SD
A	800	68.4 ± 3.1
B	1200	60.7 ± 2.5
C	1600	52.3 ± 2.9

(*Source: Histological analysis, Table 2*)

Statistical Findings
ANOVA followed by Tukey's post-hoc test confirmed significant differences between all three groups for both ISQ and BIC values. The lowest drilling speed (800 rpm) consistently yielded superior results in terms of initial stability and bone regeneration potential.
These findings suggest that lower drilling speeds during osteotomy preparation positively influence both mechanical anchorage and biological integration of dental implants (Tables 1 and 2).

DISCUSSION
The present study evaluated the influence of osteotomy drilling speed on primary implant stability and bone healing in cortical bone conditions. The findings demonstrated that lower drilling speeds significantly enhance both implant stability and bone-to-implant contact (BIC), suggesting a favorable biological and mechanical response.
Primary stability is a critical determinant of implant success, particularly in dense cortical bone where mechanical engagement is essential (1). Our results align with previous studies indicating that reduced drilling speeds minimize thermal damage, preserving bone viability and enhancing initial implant anchorage (2,3). The highest ISQ values observed in the 800 rpm group corroborate the hypothesis that slower drilling supports better mechanical retention (4).

Thermal injury during osteotomy is a well-recognized factor contributing to delayed osseointegration and potential implant failure (5). Eriksson and Albrektsson established that bone tissue exposed to temperatures exceeding 47°C undergoes irreversible necrosis (6). Higher drilling speeds, as seen in Group C (1600 rpm), likely generated greater frictional heat despite irrigation, leading to compromised healing capacity, reflected in the lower BIC percentages (7). This is consistent with findings by Brisman, who reported increased bone temperature with elevated rotational speeds (8).

Adequate irrigation is essential to counteract heat generation; however, it may not fully mitigate the thermal risks associated with excessive drilling speeds (9). Studies have shown that even with copious cooling, higher rpm values can adversely affect bone microarchitecture and reduce osteoblastic activity at the implant interface (10,11). The histological outcomes in our study, indicating superior new bone formation in the low-speed group, support these observations.

Additionally, lower drilling speeds may contribute to better preservation of bone chips within the osteotomy site, which act as a natural scaffold for bone regeneration (12). This biological advantage, coupled with reduced thermal insult, promotes favorable conditions for secondary stability through enhanced bone remodeling (13).

Clinical protocols often prioritize efficiency, leading to the adoption of higher drilling speeds for time-saving purposes. However, this approach may inadvertently compromise long-term outcomes, particularly in cortical-rich anatomical regions such as the mandible (14,15). Our findings advocate for a more conservative drilling strategy, emphasizing lower speeds with effective irrigation to balance surgical efficiency with biological preservation.

Despite the promising results, this study has limitations, including its in vitro design, which may not fully replicate in vivo physiological conditions such as vascularization and cellular responses. Further clinical studies are warranted to validate these findings in human subjects and assess long-term implant survival rates under varying drilling protocols.

CONCLUSION

In conclusion, the study reinforces the critical role of drilling speed in implant dentistry. Lower rotational speeds during osteotomy preparation enhance primary stability and promote superior bone healing, thereby potentially improving overall implant success rates. Clinicians should consider adopting low-speed drilling techniques, especially in dense bone scenarios, to optimize patient outcomes.

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